

HIGH VELOCITY PRESTRESSED SHAFT FOR DEGASSER OR PUMPING APPLICATION IN MOLTEN METAL

Cross-Reference of Related Application

5 This application is a continuation-in-part of U.S. Patent Application Serial No. 09/130,937, filed August 7, 1998, for "Advanced Motor Driven Impeller Pump for Moving Metal in a Bath of Molten Metal."

Background of the Invention

10 This invention is related to a degassing apparatus for agitating and injecting a gas into molten aluminum to remove hydrogen gas. The apparatus has a shaft which includes a prestressed, tubular shield that is in a state of longitudinal compression as it is being rotated.

15 Hydrogen gas becomes entrapped in aluminum during the recycling process and must be removed because the aluminum makes a brittle casting. Humidity also reacts with oxygen and becomes aluminum oxide forming end products of aluminum plus hydrogen.

20 Conventional practice is to agitate the aluminum using nitrogen and/or other gases (argon, chlorine, carbon dioxide) in a process called degassing. Conventional agitating devices have a short life because the heat of the molten aluminum rapidly corrodes or burns many materials used for the shaft connecting the motor to the agitating impeller. Heat resistant graphite tubing is used to protect the shaft, usually with a ceramic shielding. However, high-speed shaft vibrations cause cyclical tensile stresses. Graphite has very poor tensile strength and therefore is unsuitable for high speeds. Graphite also has a very short life (days) because it burns at the metal line.

Summary of the Invention

The broad purpose of the present invention is to provide an improved agitator shaft structure for use in either degassing or pumping molten metals, such as aluminum. Preferably, the shaft is enclosed in a tubular shield made of materials highly resistant to the heat of the molten aluminum, such as graphite or ceramic. If graphite is used, the ceramic shielding should be similar to that disclosed in my pending patent application serial no. 09/130,937, filed August 7, 1998.

In the preferred embodiment of the invention, the shaft structure employs a hollow tubular metal shaft. A motor is connected to the upper end of the shaft, and an agitator impeller to the lower end, in the molten metal. A tubular shield of a material that is heat-resistant in molten aluminum, encloses the shaft. A pair of fasteners mounted on the upper and lower threaded ends of the shaft clamps the shield in a state of longitudinal compression. The compression prevents the shield material, such as a ceramic, from experiencing tensile loads as the vibrating shaft is rotated. Further, the shield and the shaft are dynamically balanced, to reduce shaft vibrations.

Nitrogen or another scrubbing gas is introduced into the upper end of the shaft and delivered to orifices in the lower end of the shield into the molten aluminum for degassing hydrogen from the metal.

The preferred shaft assembly has a longer life, and can be rotated at higher speeds than a shaft using a similar shield material that is not prestressed. The shaft assembly can be used as a pump member, or in other applications where a shaft is disposed in molten metal.

Still further objects and advantages of the invention will become readily apparent to those skilled in the art to which this invention pertains upon reference to the following detailed description.

Description of the Drawings

5 The description refers to the accompanying drawings in which like reference characters refer to like parts throughout the several views, and in which:

FIGURE 1 is a longitudinal sectional view through a degassing apparatus having a prestressed shaft assembly illustrating the preferred embodiment of the invention;

10 FIGURE 2 is an enlarged bottom view of the degassing apparatus, as seen along lines 2-2 of Figure 1;

FIGURE 3 is a sectional view taken along lines 3-3 of Figure 1;

FIGURE 4 is an enlarged sectional view of the lower ends of the inner shield with the shaft and lower clamping nut omitted for clarification;

FIGURE 5 illustrates an alternative drive system for the shaft; and

15 FIGURE 6 illustrates the shield modified when the apparatus is being used as a pump.

Description of the Preferred Embodiment

Figure 1 illustrates a preferred degassing apparatus 10. Apparatus 10 is suspended by any suitable means, not shown, in a bath of molten aluminum 12. For
20 illustrative purposes, the aluminum is being recycled and contains hydrogen gas. Nitrogen gas is delivered by the degassing apparatus to a lower portion of the bath of aluminum, to remove the hydrogen from the molten metal.

Apparatus 10 comprises a gas supply fitting means 14, and a rotatable shaft assembly, which includes a multi-layer shield assembly including an outer tubular ceramic shield 16 and an inner tubular ceramic shield 18. Shield 18 is telescopically disposed in shield 16, and their adjacent cylindrical surfaces attached together by a layer of ceramic cement 20. More than two shield layers can be employed. The overall thickness of the shield is proportional to the shaft load.

The upper ends of shields 16 and 18 are flush and engage an annular seat 21 in a tapered gas supply fitting 22. A foil gasket 23 is disposed between the upper shield ends and seat 21 to form a gas-tight seal. The shields are slidably engaged with opening 23a in fitting 22.

The lower end of outer shield 16 extends below the lower end of the inner shield, and has a cup-shaped bottom 24 forming a gas chamber 26.

A multi-vaned agitating impeller 28 is attached by a ceramic cement 29 to the lower end of the outer shield adjacent the lower end of the inner shield to minimize tensile stress on the two shields, and to take advantage of the ceramic's high shear strength properties. The impeller could be threaded to the driving shaft.

Referring to Figures 1 and 2, bottom 24 of the outer shield has a plurality of sonic orifices 32 for delivering nitrogen from gas chamber 26 toward the bottom of the bath of molten metal. The bottom location of the orifices and the downward direction in which they deliver the nitrogen gas is intended to increase the residence time of the rising nitrogen gas in the metal.

An elongated tubular alloy steel shaft 34 is telescopically disposed within the inner tubular shield, and has its longitudinal axis concentric with that of the two ceramic shields.

The lower end of shaft 34 is externally threaded at 36, and extends below the lower end of the inner ceramic shield.

Referring to Figure 4, the lower end of shield 18 has axially extending teeth 37. A washer 38 is seated on the lower end of the inner shield, and around the lower end of shaft 34. Washer 38 has axial teeth 39 meshed with teeth 37 to drive the shaft. A lower clamping nut 40 is threadably mounted on the lower end of shaft 34.

The ceramic shields cooperate to support the drive shaft axis concentric with the impeller axis of rotation to reduce vibration of the shaft caused by the rotating impeller.

Gas supply fitting 22 is hollow, externally tapered and has a bore 42, which receives the upper end of shaft 34. Fitting 22 has an internal annular shoulder 44 below the upper end of the shaft and above the upper ends of the two ceramic shields. A series of belleville springs 46 are seated on shoulder 44 around the shaft. An upper clamping nut 48 is threadably mounted on the shaft above the belleville spring. Nut 48 has a pair of openings 50 for receiving a spanner wrench (not shown) for tightening the nut on the shaft to compress springs 46.

An annular guide lock 52 is threadably mounted on the shaft in abutment with clamping nut 48 to lock it in an adjusted position. The guide lock carries an annular seal 54 to provide a gas-tight seal between the guide lock and gas fitting 22.

A rotary power means 56 is drivingly connected to the shaft so that the shaft, the two ceramic shields and the impeller rotate as a unit. As such, the unit can be dynamically balanced for operation at rotary speeds greater than 400 rpm versus present top speeds of 200 rpm.

To assemble the degassing assembly, the shaft is inserted in the inner ceramic shield. Washer 38 and lower clamping nut 40 are threadably mounted on the lower end of the shaft. The washer is locked in place to the end of the inner shield by nut 40. The outer surface of the inner shield is then coated with ceramic adhesive 20 and inserted in the outer shield until the upper end of the inner shield is flush with the upper end of the outer shield. This then forms an integral laminated shielding unit for the shaft.

Gas fitting 22 is then mounted on the upper end of the shaft after foil gasket 23 has been disposed between the shields and the gas fitting. The belleville springs are inserted in the bore of the gas fitting. When adhesive 20 has cured, upper clamping nut 48 is tightened with a spanner wrench, not shown, to longitudinally compressively prestress both the inner and the outer ceramic shields between the upper and lower clamping nuts. This prestress prevents the application of a distinctive tensile stress on the ceramic shields as the shaft assembly is being rotated. Guide lock 52 is inserted with seal 54 in the gas fitting bore to lock the upper clamping nut in its adjusted position.

The entire length of the inner shield is prestressed with that part of the outer shield cemented to the inner shield. The outer shield is attached to the impeller in a location such that essentially only a shear force is applied to the lower end of the outer shield by the impeller load. The ceramic is available from Alphatech, Inc. of Cadiz, Kentucky and has an excellent shear strength so that it experiences basically only a shear force from the impeller.

Nitrogen gas is delivered from a source 55 through a conduit 56 to a coupling 58. Coupling 58 is stationary, but permits the rotation of on an outer hollow, tapered gas fitting 60 attached to gas fitting 22. The gas passes down through a passage 62, through shaft

34 into gas chamber 26, and out through sonic orifices 52 into the molten aluminum where it mixes with the aluminum to remove hydrogen gas.

Small orifices that can not erode due to gas velocity and temperature, provide smaller gas bubbles to better penetrate into the aluminum bath. Degassing is improved because it is proportional to the residence time of the gas in the aluminum and inversely proportional to the diameter of the bubble. A greater surface area of the gas bubbles is exposed to the molten aluminum to "scrub" the hydrogen.

The two ceramic shields cooperate to make the drive shaft axis concentric with the impeller axis to reduce vibration of the shaft and the shields caused by the rotating impeller.

The shielding unit automatically compensates for the differences in the thermal elongation of shaft 34 and the shielding unit caused by the temperature of the molten metal. Both the inner and outer shields are formed of the same material so that they have the same coefficient of thermal expansion. However, the shaft 34 is of a steel alloy metal, which has a different coefficient of thermal expansion. Consequently, to compensate for the differences of thermal expansion, as the shaft elongates in response to thermal expansion, lower nut 40 will move slightly downwardly. The two shielding units will then slide downwardly with the nut because the upper end of the shields are slidably mounted in opening 23a. The belleville springs are arranged so the upper and lower nuts maintain their prestress on the shields, while at the same time permitting the shaft to elongate or shorten at a different rate than the shields. The shields and the impeller are thus floatably carried on the shaft.

Referring to Figure 5, an alternative coupling structure 200 is illustrated for connecting a source of gas 202 to the hollow shaft. In this case, a universal gas coupling 204 is rotatably connected by a shaft 206 to a bell structure 208. Bell structure 208 is mounted on a pair of supports 210 and 212 to a base support 214 by bearing means 216 and 218. The outer bell is in turned threadably coupled to the driving bell 220, which is connected to shield 216'. Drive shaft 34' extends above the shield and has an upper end 222 threadably connected to shaft 206. A clamping nut 224 is threadably mounted on the shaft, and a K-wool or equivalent gasket mounted between the upper end of the shaft drive 34' and shaft 206. Seal 54' provides a gas tight seal between the shaft and the gas fitting. Gear means 230 connected to a motor drive 232 are mounted on shaft 206 to rotate the hollow shaft 34' and bell structure 208.

Figure 6 shows a variation of the lower end of the drive shaft in which the invention is used as a pumping member rather than as a degasser. In this case, shaft 34" is threadably connected to a lower nut 40". A washer is mounted between the nut, and the lower end of inner shield 18" and a step 19' on the outer shield 20". The two shields are attached together in a laminated fashion by an adhesive 18". In this case, the lower end of the outer shield is threaded at 300 for receiving a pumping member 302.

Note there is a gas chamber 26" at the lower end of the hollow drive shaft to allow inert gas to saturate foil gasket 304. The impeller 302 could be provided with orifices at the bottom of chamber 26 if utilized as a degasser shaft assembly.

The advantage of this arrangement is that both shields are in positive compression. The structure is easy to assemble. If the shaft is used as a pump the nitrogen source 202

is optional if no orifices are provided on impeller 302. The gas makes the structure leak proof.

Having described my invention, I claim: